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REPORTS OF OBSERVATORIES.[1]

Some years ago the Committee on Publication of the Astronomical Society of the Pacific inaugurated the plan of obtaining annual reports from the observatories of the Pacific Coast. The plan met with success, and has been carried out with some modifications and interruptions, ever since. The committee hopes to be able to publish, from now on, reports from all the observatories, both great and small, situated between the Rocky Mountain region and the Pacific Coast.

In addition to the observatories from which reports are printed below, there are a number of others possessing small equipments which are used chiefly for purposes of instruction. Among these may be mentioned the observatory of the University of Washington at Seattle, which has a 6-inch refractor, chronometer, and sextant; the observatory of the University of Oregon, at Eugene, which is provided with transit, sidereal clock, and sextant; the observatories of the University of the Pacific at San Jose and of Santa Clara College, both of which have small refractors and minor instruments; the Chabot Observatory, which forms a part of the public school system of the city of Oakland, and possesses an 8-inch refractor, together with a very complete equipment of accessory instruments; the Coast and Geodetic Survey Observatory in San Francisco, containing a transit and a zenith telescope, which is a base station for telegraphic longitude work. Captain Rogers, who is in charge of the observatory, reports that no work was done there during 1905, the last work being the Transpacific difference of longitude, San Francisco-Manila, in 1903-4.

CHAMBERLIN OBSERVATORY, DENVER, COLORADO.

During the year 1905 the chief observations of the Chamberlin Observatory were upon the comets then visible. Experiments were also made about special methods of noting time and certain varieties of personal equation.

H. A. Howe, *Director.*

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[1] Arranged alphabetically according to name.

INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.

The programme of the International Geodetic Association for observing variations of latitude was continued throughout 1905 without modification or interruption. Good observing weather prevailed throughout the year except during the month of January. The rainfall for the year was 29.1 inches. The maximum temperature was 113° F., on July 7th; the minimum, 21°, on December 24th. During the early part of July a "warm spell" prevailed, during which the following maximum temperatures were observed on a thermometer hanging on the north side of the Observatory inside the surrounding latticework.

July 3,	100°	July 7,	113°
4,	101	8,	108
5,	108.5	9,	104
6,	107	10,	103

The three longest intervals without observations were ten nights in March, seven in April, and eight in November. The first and third of these were caused by unfavorable weather and the second by a combination of unfavorable weather and absence of the observer from the station.

The following table gives a summary of the observations made for the variation of latitude. The first column contains the number of determinations made each month, the second column the number of nights upon which observations were made, the third column the number of complete nights (16 determinations), the fourth column the greatest interval each month during which no observations were obtained.

1905.	Pairs.	Nights.	Nights.	Nights.
January	144	13	6	6
February	231	17	11	5
March	184	14	9	10
April	189	18	8	7
May	224	17	10	5
June	214	20	10	3
July	247	17	13	3
August	280	19	16	4
September	254	17	14	4
October	251	17	14	4
November	164	12	8	8
December	178	13	8	4
Totals	2560	194	127	
Means	213	16	10.5	5

The probable error of a single determination of the latitude varied, as in previous years, between ± 0″.10 and ± 0″.11.

SIDNEY D. TOWNLEY, *Astronomer-in-Charge.*

LICK OBSERVATORY, MT. HAMILTON, CALIFORNIA.

The output of observational and related results along the lines of our current programme was considerably reduced for the year 1905 on account of several unusual conditions.

The total solar eclipse of August 30, 1905, was to occur under a combination of circumstances as to duration, location, season, and probable weather, so favorable that we could not hope to see them equaled for a great many years to come. The burden of preparing the very extensive equipments of the expeditions to Labrador, Spain, and Egypt fell upon Messrs. CURTIS, CAMPBELL, and PERRINE, and much of their time from January 1st until shipment was made in June was devoted to this important subject. Minor parts in these preparations were assigned to several other members of the staff.

Dr. CURTIS was absent, in connection with the Labrador expedition, from June to October. After his return to Mt. Hamilton his duties consisted largely in preparing additional plans and equipment for the D. O. Mills expedition to Chile. He left on December 27th to take charge of the expedition, on Cerro San Cristobal, Santiago, Chile, for a period of five years.

Messrs. CAMPBELL and PERRINE were absent from June to November, in connection with the Spanish expedition.

Professor HUSSEY left Mt. Hamilton on June 1st, was absent four months in connection with the Egyptian expedition, and returned to this country early in October to assume his new duties as Director of the Detroit Observatory.

The general plans and results of the three eclipse expeditions have been described already in these *Publications* (Nos. 105 and 106), and it does not seem necessary to repeat them here, although they form an important part of our work in 1905.

The observing programme of the D. O. Mills expedition was continued uninterruptedly through the year, except that Acting Astronomer WRIGHT was alone in the work after September, Assistant H. K. **Palmer** having returned to this country. The exact number of spectrograms for radial velocities of the stars obtained in the year will not be known to me for a few weeks yet, but it amounts to several hundred. All of these have been measured approximately and many of them definitively.

About one year ago Mr. **Mills** arranged, with great generosity, to continue the expedition for five additional years, and at the same time to improve and add to its equipment.

The meridian-circle department, in charge of Astronomer R. H. **Tucker**, obtained results as follows:—

The measurement of the graduation errors of the 10′ divisions of the fixed circle of the Repsold instrument was completed in April. The preliminary reductions had been kept up during the progress of the work, which began eighteen months earlier, and the final corrections were promptly derived and published in *L. O. Bulletin* No. 85. The method of simultaneous reading of both circles was employed up to this point, all the 10′ divisions of a single degree of the movable circle being compared successively with the 10′ divisions of the fixed circle.

Mr. **Elliott Smith**, Carnegie Assistant for two years ending July 1st, took part in the measures and in the corresponding computations.

Some measures were made of the intermediate 2′ divisions, extending over a degree of each circle. One observer reads alone in this process, which consists of direct measurement, by means of the circle microscopes, from the nearest 10′ divisions. Special 2′ divisions required in the observation of the fundamental programme have also been measured. The complete measurement of all the 2′ divisions is not at present contemplated.

Observations of a fundamental character were begun in July, including several co-ordinated schemes. Circumpolar stars, including *Polaris*, are observed at successive upper and lower culminations. Zenith stars are included in each series for the investigation of certain classes of systematic error. Stars of large zenith-distance, north and south, are observed for test of the corrected refractions, already investigated here. And the design is to provide fundamental determinations of a series of stars from the pole to high southern declination, which shall serve as the basis for the observation of the places of a large number of fundamental stars.

Observations were made for about half of a list of latitude stars used by Professor C. L. DOOLITTLE, of the Flower Observatory. Both co-ordinates were determined, as it is not considered to be practical economy to observe declination only.

The reductions of the observations of the zodiacal list, completed in 1904, were carried on during the past year nearly to completion.

The magnitude equation in the right ascension of the *Eros* stars was investigated, and the results were published in *L. O. Bulletin* No. 72.

Astronomer W. J. HUSSEY's observational work at Mt. Hamilton before June 1st included about 300 complete measures of double stars and the discovery of approximately 100 new pairs.

Dr. R. G. AITKEN's work for the year was as follows:—

Observing:

(1) 1,350 measures of double stars with 36-inch telescope. The observing-list included the more important known binary systems, 130 stars discovered, but only partly measured, by W. J. HUSSEY, and the new stars discovered by the observer.

(2) 340 new double stars discovered with the 12- and 36-inch telescopes. These are all under 5″, 76 per cent. of them under 2″, and 31 stars under 0″.25. This work involved the examination of over 11,000 stars.

(3) Measures of the satellites of *Uranus* and *Saturn* and Satellite V of *Jupiter* with the 36-inch telescope. Also observations of eclipse phenomena of *Saturn's* satellites.

(4) Measures of comets, *a, d,* and *e* 1904 and *a* and *b* 1905, mostly with the 12-inch telescope, a few with the 36-inch telescope.

Computing:—

(1) Elements and ephemeris of Comet *d* 1904.
(2) Elliptic elements and ephemeris of Comet *e* 1904.
(3) Orbit of β 395=*Ceti* 82.
(4) Orbit of Σ 1998=ξ *Scorpii*.
(5) A catalogue of the orbits of visual binary stars.

One hundred and eighty-nine negatives were obtained with the Crossley reflector, principally by Dr. PERRINE, astronomer in charge of the instrument. They consisted chiefly of photographs of the faint satellites of *Jupiter* and *Saturn* and of the satellite of *Neptune.* Those relating to *Jupiter* led to Dr. PERRINE'S discovery of the sixth and seventh satellites and formed the basis for the determination of their orbits. From June to November the Crossley reflector was in immediate charge of Mr. SEBASTIAN ALBRECHT, who reobserved the new satellites after their conjunction with the Sun, securing a considerable number of excellent plates. He also obtained a few observations of *Saturn's* ninth satellite. The photographs obtained by Mr. ALBRECHT numbered about sixty. Measures and reductions of several of the summer plates were made by Mr. ALBRECHT and Mr. SMITH.

The performance of the new mounting of the Crossley reflector, completed late in 1904, has fully met expectations. Dr. PERRINE'S description of the instrument is contained in *Lick Observatory Bulletin* No. 78.

The work with the Mills spectrograph has been prosecuted continuously throughout the year. The observational part was borne largely by Dr. MOORE, who was in charge of the spectroscopic department during the absence of the eclipse observers. Dr. CURTIS observed regularly during the months that he was on the mountain, and Mr. BURNS assisted occasionally. Altogether 475 spectrograms were obtained with the three-prism Mills spectrograph. Mr. K. BURNS, Carnegie Assistant, measured 398 plates definitively; Dr. CURTIS measured about 75 definitively and 30 approximately, and Dr. MOORE measured 75 definitively and 200 approximately. Dr. TURNER, of the University of the City of New York, spent the months of July and August here, assisting in the observations and acquiring experience in the measurements and general methods of radial velocity determinations.

Dr. CURTIS made a special study of the quadruple system of *Castor,* based on spectrograms obtained with the Mills spectrograph.

One hundred and fourteen spectrograms were made with the one-prism instrument; 28 of *X Sagittarii* and 3 of *Nova Aquilae* No. 2, by Dr. MOORE; and 34 of *T Vulpeculae,* 40 of

Y Ophiuchi, and 9 of *U Aquilae,* by Mr. ALBRECHT, in connection with his thesis work looking to the degree of Doctor of Philosophy. These have nearly all been measured by the observers.

Mr. J. D. MADDRILL, Fellow, made observations with the Rumford photometer as follows: Variable stars and the asteroid *Urda,* 118 comparisons with several neighboring stars, involving about 4,800 settings; *Pleiades* standards on four nights, requiring 300 settings; and for the effects of sky-illumination, position-angle, and other variable factors, on eight nights, involving 400 settings. Eighteen eclipses of *Jupiter's* satellite I were observed for Professor NEWCOMB. The positions of *Nova Aquilae* No. 2 and of *Urda* were determined with the micrometer of the 12-inch refractor.

Messrs. ALBRECHT and BURNS secured photographs of the Sun, with the camera of 40-foot focus, during the twenty days preceding and following the eclipse date, August 30th.

Mr. ELLIOTT SMITH, Fellow from July 1st, assisted in the observations with the Crossley reflector, in the reduction of Dr. AITKEN'S satellite and comet observations, and made 15 micrometric observations of comets, 12 of asteroids, and 9 photographs of Comet *c* 1905.

Lick Observatory Bulletins Nos. 67 to 88 were published within the year.

No reference is made in the foregoing abstract to a large number of minor duties discharged by the members of the staff during the year.

W. W. CAMPBELL.

LOWELL OBSERVATORY, FLAGSTAFF, ARIZONA.

Visual observations on *Mars* at the last opposition were begun by the Director on January 13th and continued until August 15, 1905. Previous to this observations on the planet were made by Mr. LAMPLAND, beginning about the middle of September, 1904. As at the earlier oppositions, the observational data consisted of drawings, notes and measures. From the experience gained by Mr. LAMPLAND in planetary photography on *Jupiter* and *Saturn* during the two years previous to this opposition, it was possible to supplement the above data with photographs of the canals and other surface markings of the planet.

From January 13th to August 15th, the most favorable months of the opposition, the series of drawings, notes, and measures give nearly an unbroken record of the phenomena presented by the disk from day to day. Opposition occurred on May 8th, so that the series of continuous observations cover a period of about four and three months before and after opposition respectively. The observations at this opposition confirm and extend those made at the earlier oppositions. In particular may be mentioned the observations on the double canals, the varying visibility of the surface-markings on different parts of the disk with the planet's season and the canal development brought to light by the observations made in 1903. For a detailed account of the observations and discussion of the various phenomena reference is here made to the *Annals* and *Bulletins* of this observatory.

A new determination of the position of the axis of *Mars* will be found in *Bulletin* No. 24. The investigation takes into account the determinations of SCHIAPARELLI, LOHSE, CERULLI, STRUVE, and all measures made by the writer, including those made at the opposition of 1905. (See *Bulletin* No. 24.)

From May 10th until June 30th, visual observations and photography were carried on together. After this photographs were made at intervals until the middle of July. The later photographs, however, are much inferior to the earlier ones, due to the smallness of the disk and the increased phase. Several hundred images of the planet were obtained, and a great many of these have good definition, showing the canals and other surface-markings distinctly. A preliminary account of the work has been given in *Bulletin* No. 21, and in a paper presented to the Royal Society. A word in regard to the quality of the observing conditions here may not be out of place. The steadiness and transparency of the atmosphere may be judged from the large amount of detail shown in the planetary negatives with the large equivalent focal length used (about 148 feet). As further evidence in regard to the transparency may be mentioned the addition of faint stars to the chart of faint stars visible in the large telescopes of the Harvard, Washington, and Lick observatories. (See *Popular Astronomy*, Vol. XIII, No. 7.)

During the period covered by the *Mars* observations *Venus* was observed from time to time, taking advantage of the most perfect conditions.

Various theories have been advanced from time to time explaining certain Martian phenomena, notably the double canals, as being optical products of one sort or another, or illusions. It has been deemed important to investigate these theories critically in order to obtain definite knowledge of the true value of Martian observational data and the deductions made from them. Theory and experiment, at the telescope and elsewhere, as well as the direct results of observation, applicable as criteria for tests of these theories, show conclusively that the phenomena in question cannot be spurious results of observation. Bearing directly on the problem of the double canals, the separative power of glasses has been dealt with from the standpoint of theory and experiment in *Bulletin* No. 5, and in *Popular Astronomy* (Vol. XII, No. 9). The diplopic, interference, and illusion theories have been discussed in detail in *Bulletin* No. 15.

The programme of spectroscopic work, in charge of Mr. SLIPHER, has included: (*a*) Investigations on the spectra of the planets *Venus, Mars, Jupiter,* and four brighter satellites —*Saturn, Uranus,* and *Neptune*—for study of their atmospheres. By the use of isochromatic plates and specially preppared plates sensitive to a large part of the less refrangible region of the spectrum, it was possible to photograph the spectra of these planets far into the red, including the region in which atmospheric absorption bands exist. For comparison-spectrum that of the Moon or Sun, at an equal altitude, has always been used, with exposures producing as nearly as possible the same density of deposit as that of the planet. Hygrometric conditions were also carefully considered in this work, so that the relative intensities of the absorption bands in the two sources might be directly comparable. For a detailed discussion of these results the reader is referred to *Bulletins* Nos. 13, 16, and 17. (*b*) Radial velocity determinations have included a short miscellaneous list of stars and the ten standard velocity stars proposed by Professor FROST (*Astrophysical Journal,* Vol. XVI, p. 169). The published results of this work will be found in *Bulletins* Nos. 11 and 23, and in the

Astrophysical Journal (Vol. XX, No. 2; Vol. XXII, Nos. 1 and 5.)

During January and February of this year Mr. LAMPLAND has made a series of measures for position on the sixth satellite of *Jupiter*.

General celestial photography and micrometric work has been carried on by Mr. DUNCAN, Lawrence Fellow at this observatory. Photographic work for charting purposes was done with the 24-inch refractor and a large portrait-lens mounted on its tube. The photographs with the visual telescope were made in the focal plane on isochromatic plates without color screen, the secondary spectrum of all but the brightest stars being too faint to affect perceptibly the plate.

Mr. DUNCAN made a series of photographs of Comet *c* 1905 (GIACOBINI) with the large portrait-lens and a smaller lens of about 8 inches focal length. These plates show the development of the comet from the first appearance of the tail until a short time before perihelion passage, when the tail was shown to have attained a length of over eleven degrees. A series of measures of comets GIACOBINI, BROOKS, and KOPFF is still in progress.

In May, 1905, the old Bond spring governor driving-clock of the 24-inch telescope was replaced by a large and powerful clock of the conical-pendulum type, made by WM. GAERTNER & Co., of Chicago. The excellent performance of this clock contributed largely to the sucess in obtaining the photographs of the canals of *Mars*.

The varied programme of spectroscopic work carried on makes it necessary that the spectrograph be adjustable for work in different regions of the spectrum. The original mounting of the prisms did not give the rigidity and stability required, unless the clamping screws on the top plate of the prism mountings were screwed down so tight that the pressure destroyed the homogeneity of the prisms. To remedy this defect the instrument is being remodeled by BRASHEAR, according to designs by Mr. SLIPHER. The prisms are being remounted and the collimator provided with a curved slit.

The mounting of the 6-inch Clark refractor is being remodeled and provided with driving mechanism, in the hope that this instrument may be utilized as a guiding telescope for photographic work with portrait lenses.

PERCIVAL LOWELL, *Director.*

NAVAL OBSERVATORY, MARE ISLAND, CALIFORNIA.

The equipment of the observatory consists of two Stackpole broken-back transits used in the time service; four standard clocks, two sidereal and two mean-time, and a mean-time transmitter used in sending out the time; and a 5-inch Clark refractor of the type devised for observing the transit of *Venus.* In addition to these instruments there are others used in nautical and meteorological work and a large number of chronometers belonging to the Navy.

The observatory was established primarily for furnishing the time to the Navy Yard and the west coast, and for investigating the rates of chronometers. The time is furnished daily, except Sundays and holidays, to the Western Union Telegraph Company, and goes over the wires as far east as El Paso, Texas, and Omaha, Nebraska; so that it reaches all points west of the Rocky Mountains.

During the year from fifty to one hundred chronometers are investigated and issued to the naval service. Some of these are issued to ships of the Pacific fleet, assigned to the west coast of the United States, but rather more go to the Naval Station at Cavite, Philippine Islands, for the use of the Asiatic fleet.

A new observatory with more complete equipment has been recommended for several years, but provision for it has not yet been made by Congress.

T. J. J. SEE.

SOLAR OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON, MT. WILSON, CALIFORNIA.

The purpose of the Solar Observatory may be defined as follows:—[1]

(1) The investigation of the Sun (*a*) as a typical star, in connection with the study of stellar evolution; (*b*) as the central body of the solar system, with special reference to possible changes in the intensity of its heat radiation, such as might influence the conditions of life upon the Earth.

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[1] The detailed program of solar research is given in "Contributions from the Solar Observatory," No. 3 (reproduced in a recent number of the Publications of the Astronomical Society of the Pacific.)

(2) The choice of an effective mode of attack, involving (*a*) the application of new methods in solar research; (*b*) the investigation of stellar and nebular phenomena, especially such as are not within the reach of existing instruments; and (*c*) the interpretation of these celestial phenomena by means of laboratory experiments.

(3) The design and construction of a large reflecting telescope and of new types of instruments peculiarly adapted for the purposes in view, with special reference to the possibilities of research through the study of celestial objects under laboratory conditions.[1]

(4) The accomplishment of the foregoing purposes at a site where the atmospheric conditions have been shown to be exceptionally favorable: Mt. Wilson (5,886 feet), in Southern California, (lat. +34° 13′ 26″; long. W. 118° 3′ 40″).

(5) The furtherance of international co-operation in astrophysical research through the invitation to Mt. Wilson, from time to time, of investigators specially qualified to take advantage of the opportunities afforded by the Solar Observatory.

Staff.—My principal associates on Mt. Wilson are FERDINAND ELLERMAN and WALTER S. ADAMS, assistant astronomers, and HENRY G. GALE, assistant physicist. Mr. ADAMS has been appointed superintendent of the computing division, and the staff of computers is now being organized. At the Pasadena instrument-shop the work of construction is carried on under the supervision of Professor G. W. RITCHEY, astronomer and superintendent of instrument construction.

Professor WINSLOW UPTON, Director of the Ladd Observatory of Brown University, and Professor L. H. GILMORE, of Throop Polytechnic Institute, were engaged in special work at the Solar Observatory during the summer of 1905.

During 1905 the following expeditions have conducted observations on Mt. Wilson in co-operation with the Solar Observatory:—

Hooker Expedition—EDWARD E. BARNARD, astronomer of the Yerkes Observatory, in charge.

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[1] See "The development of a New Observatory," Publications of the Astronomical Society of the Pacific, Vol. XVII, p. 41, 1905.

Smithsonian Expedition—CHARLES G. ABBOT, aid acting in charge of the Smithsonian Astrophysical Observatory, in charge; LEONARD R. INGERSOLL, University of Wisconsin, assistant.

Investigations in progress.—Although the programme of observations must naturally be a restricted one until the completion of the instrumental equipment, it has nevertheless been possible to commence systematic work in five departments: (1) daily photography of the Sun with the photoheliograph; (2) daily photography of the Sun with the spectroheliograph; (3) photography of the spectra of sun-spots and flocculi; (4) photography of stellar spectra with a spectrograph of high dispersion; (5) laboratory investigations. The Snow telescope has been employed in all of the solar and stellar work; various tests of this instrument have been described in previous numbers of the *Publications of the Astronomical Society of the Pacific.*

Work with the spectroheliograph.—A temporary spectroheliograph, built for use with the Snow telescope pending the construction of the 5-foot spectroheliograph, gave excellent results during the summer of 1905. The new 5-foot spectroheliograph was completed in our instrument-shop and set up on Mt. Wilson in October. A description of this instrument has been published in *Contributions from the Solar Observatory,* No. 7, (*Astrophysical Journal,* January, 1906). Its principal advantages over the Rumford spectroheliograph are the larger aperture of the collimating and camera objectives, obviating loss of light at the Sun's limb; the possibility of photographing the entire disk with high dispersion; the ease of attaching slits of different curvatures; the possibility of using from one to four prisms, and either one or two mirrors in the optical train; the wide range of speed afforded by the driving mechanism; the elimination of the danger of distortion arising from imperfect synchronism in the motion of solar image and plate; and the ease of manipulation due to the general design and the improvement of details.

The new spectroheliograph has been in regular use since October 10th. Photographs of the Sun taken daily include H_1 plates, H_2 plates, and hydrogen plates. Photographs of the prominences are also taken regularly when circumstances permit. During the broken weather of the rainy season, when the conditions are less favorable than in the summer months, the daily series is necessarily interrupted. At present experiments are in progress with high dispersion, using four prisms in the optical train. In certain classes of work the advantages of such high dispersion are very considerable, and it can soon be determined what systematic work in photographing the Sun with the dark lines can be undertaken to advantage with this instrument. It has been found that two prisms suffice to give good photographs of the hydrogen flocculi, on account of the high dispersion of the prisms employed and the considerable focal length of the spectroheliograph. Good photographs of the iron flocculi made with the line λ4045 are also taken frequently with the same dispersion.

The hydrogen photographs are of special interest, as they are the first to show the dark hydrogen flocculi over the entire disk of the Sun. In photographs made with the Rumford spectroheliograph the hydrogen flocculi are shown only in comparatively narrow zones. Several new phenomena of considerable interest have been brought out in the recent work. It has been ascertained that sun-spots on hydrogen plates are frequently surrounded, wholly or partially, by a narrow ring of bright hydrogen flocculi, lying just outside of the penumbra. Since ordinary hydrogen flocculi are dark, such bright rings are likely to prove of significance when systematically studied. They seem to have no counterpart on the photographs of calcium flocculi. Very dark hydrogen flocculi, found in only one or two instances on the Rumford spectroheliograph plates, are very common on the Mt. Wilson photographs. These flocculi, which are much darker than the ordinary hydrogen flocculi, have been long and narrow in form in all cases hitherto encountered. Photographs of the $H\delta$ and $H\epsilon$ lines show that they are much strengthened and widened in these flocculi. A very significant fact, which confirms the view we have held regarding the nature of these objects, is the widening and strengthening of the H_3 and K_3 lines at the same points on the Sun. In a paper on the Rumford spectroheliograph (*Publications of the Yerkes Observatory,* Vol. III, No. 1), an illustration was given of a *dark* calcium flocculus corresponding with one of these very dark hydrogen flocculi. The spectrum of such objects had not then been photographed, but there seemed to be no doubt that this particular form of hydrogen flocculus, at least, must lie at the H_3 level. This supposition is now confirmed.

The construction of the 30-foot spectroheliograph has been greatly delayed on account of the difficulty of obtaining suitable prisms of the large aperture required. It has now been found necessary to experiment with a new form of prism, which will be built up of a series of horizontal slabs, made from telescope disks of a single melting. There is reason to believe that on account of the ease of annealing these thin plates, prisms can be constructed in this way which will give better results than large prisms of a single block of glass. There will of course be a small loss of light, due to the manner of building up the prisms, but this should not be at all serious.

Spectra of sun-spots and flocculi.—The widened lines in the spectra of sun-spots have been successfully photographed in the third and fourth order spectra of a powerful Littrow spectrograph, having a combined collimator and camera lens of eighteen feet focal length. The widened lines are well shown in these photographs,, as well as the fainter lines, first found by YOUNG's visual observations to constitute the general band of absorption in spot-spectra. The results and conclusions derived from a study of the lines affected in the photographs are given in *Contributions from the Solar Observatory*, No. 5, (*Astrophysical Journal*, January, 1906). A summary of this paper appeared in a recent number of the *Publications of the Astronomical Society of the Pacific.*

Mr. ADAMS has made a special study of the H and K lines and the motion of the calcium vapor in the flocculi. The measures of H_3 and K_3 show a general tendency to a displacement of this line toward the violet, which would correspond with an ascending motion of the high-level calcium vapor. Further measures will be required, however, before final conclusions can be drawn. H_2 and K_2 also show a displacement toward the violet. The detailed results may be found in *Con-*

tributions from the Solar Observatory, No. 6, (*Astrophysical Journal,* January, 1906).

Stellar Spectroscopy.—One of the principal objects of the Solar Observatory is to secure photographs of the spectra of certain bright stars with a high-dispersion spectrograph, on a scale comparable with that of ROWLAND'S photographs of the solar spectrum. The spectrograph used with the Snow telescope has collimating and camera lenses of 5 inches aperture and 13 feet focal length, mounted rigidly, with the slit, grating or prism train, and plate-holder, on a single massive stone pier. With the aid of a large plane grating, for the use of which we are indebted to the kindness of Professor AMES of Johns Hopkins University, the blue region of the first-order spectrum of *Arcturus* was photographed, but an exposure of fourteen hours on three successive nights was necessary. During this time the grating was automatically maintained at a constant temperature. On account of the long exposures required, it was thought advisable to experiment with prisms in place of the grating. Two of the large prisms of 63° angle (Jena glass 0.102), belonging to the 5-foot spectroheliograph, were accordingly used with a single mirror in place of the grating. Although the prisms were not large enough to receive more than one half of the light from the collimator lens, the resulting photographs were made with much less exposure time than was required in the case of the grating, while at the same time the linear dispersion is also considerably greater with the prisms. If the plan already mentioned, of constructing prisms of comparatively thin horizontal slabs, gives satisfactory results, it is probable that prisms, instead of a grating, will be employed in the high-dispersion stellar spectrograph which is to be used with the 5-foot reflecting telescope.

In a study of the less refrangible portion of the spectrum of *a Orionis,* which was photographed by ADAMS with the Snow telescope and the spectrograph just described, using a single prism, many of the lines which are widened in sun-spots, while absent or faint in the solar spectrum, have been found to be greatly strengthened. This tends to confirm conclusions reached in a study of stellar spectra of the third and fourth types with the 40-inch Yerkes telescope (*Publications of the Yerkes Observatory,* Vol. II.).

Spectroscopic laboratory.—The spectroscopic laboratory on Mt. Wilson has recently been completed and investigations have been undertaken by Mr. Gale and myself on the behavior of the lines of titanium, iron, and other substances, which are widened in sun-spots, in a magnetic field, under varying self-induction, etc. The equipment of the laboratory, which has been specially designed for work of this nature, includes a powerful Du Bois magnet for the Zeeman effect, apparatus for producing arc and spark spectra at low and high pressures and in various gases, etc. The various light sources are arranged on the circumference of a circular pier, in such a way that light from any source can be reflected from a central plane mirror to a concave mirror which forms an image of the source on the slit of a long-focus Littrow spectrograph.

Computing division.—An addition to the office and instrument-shop building at Pasadena, providing space for computing offices, is under construction. A globe measuring-machine, for the rapid determination of the heliographic positions of sun-spots and flocculi, will soon be in use. In the first design the solar photograph, observed from a distance of 60 feet with a 4-inch telescope, was optically superposed on a silvered globe ruled with meridians and parallels one degree apart and mounted so that its axis could be placed parallel to the Sun's axis for the date of the photograph. This gave good measures, but another and more precise method of measurement suggested itself as the result of experiments with this instrument. In the modified apparatus settings will be made on the flocculi with cross-hairs exactly as would be done in a measuring-machine. The cross-hairs will then be observed in projection on the globe, which will be revolved in latitude and longitude until a point on its surface coincides with their intersection. The readings of two circles on the globe will then give the desired latitude and longitude. Other instruments provided for the Computing Division include a Zeiss stereocomparator, measuring-machines for spectra, and for rectangular co-ordinates, calculating machines, etc. It is hoped that this department of the observatory will soon be completely organized.

Smithsonian expedition.—For some years Secretary LANGLEY, of the Smithsonian Institution, had been planning to send an expedition to a mountain station for the purpose of measuring the solar constant, with special reference to its possible variability. At the invitation of the Solar Observatory, the expedition was sent to Mt. Wilson, in charge of Mr. C. G. ABBOT, and remained there from May until November, 1905. The conditions proved to be extremely satisfactory for the bolographic and pyrheliometric work, and Mr. ABBOT, who was assisted by Mr. INGERSOLL, secured a large number of observations, which are now in course of reduction. It is hoped that arrangements can be made to continue this work in future years.

Publications.—The publications of the Solar Observatory already issued include the following papers:

Contributions from the Solar Observatory:

No. 1. A Study of the Conditions for Solar Research at Mt. Wilson, California.
No. 2. The Solar Observatory of the Carnegie Institution of Washington.
No. 3. A Programme of Solar Research.
No. 4. Some Tests of the Snow Telescope.
No. 5. Photographic Observations of the Spectra of Sun-Spots.
No. 6. Some Notes on the H and K Lines and the Motion of the Calcium Vapor in the Sun.
No. 7. The Five-Foot Spectroheliograph of the Solar Observatory.

Report of Director of the Solar Observatory, Mt. Wilson, California (From *Year-Book* No. 4 of the Carnegie Institution of Washington).

Pasadena instrument-shop.—The work of instrument construction has gone on very successfully at the instrument-shop in Pasadena under the direction of Professor RITCHEY. The apparatus already constructed includes a spectroheliograph of 8 inches aperture and 5 feet focal length; a stellar spectrograph of 5 inches aperture and 13 feet focal length; a solar spectrograph (Littrow type) of 6 inches aperture and 18 feet focal length; a spectroheliograph temporarily used with the Snow telescope; a globe machine for measuring solar photographs; apparatus for the study of spark spectra in air and in liquids; and many other miscellaneous instruments and apparatus used in conjunction with the Snow telescope and in the physical laboratory on Mt. Wilson. Much work has also been done on the mounting of the 5-foot reflector and in figuring concave and plane mirrors.

Five-Foot reflector.—The 5-foot mirror, which had been fine-ground by Professor RITCHEY at the Yerkes Observatory, was brought out to Pasadena last spring. It is now being figured, and the special precautions which Professor RITCHEY has taken promise to yield excellent results. The perfect equipment of the optical laboratory and the provisions made for maintaining the air at constant temperature and for excluding dust render the conditions for work extremely satisfactory. The heavy parts of the mounting have been practically completed by the Union Iron Works Company of San Francisco, and will soon be set up in a house erected for this purpose near the instrument-shop in Pasadena. The driving-clock and other parts of the mounting are under construction in our own shop, and the entire work of completing the instrument and of testing it in actual observation will be carried out before it is sent to Mt. Wilson. The steel building and dome which will contain the telescope are being constructed by the Union Iron Works Company.

GEORGE E. HALE, *Director.*

STUDENT'S OBSERVATORY, BERKELEY ASTRONOMICAL DEPARTMENT, UNIVERSITY OF CALIFORNIA.

This report covers the period from January 1 to December 31, 1905.

On July 1st Dr. A. F. GILLIHAN resigned his position as Assistant in Practical Astronomy to devote his time to private work. In recognition of his valuable services in connection with the designing and construction of the new equipment of the observatory he was given an appointment as honorary assistant. The position vacated by him was filled by the appointment of Mr. STURLA EINARSON, a graduate of the University of Minnesota.

Miss A. M. HOBE, who has been an assistant at the observatory for a number of years, resigned her position on December 1st to accept an appointment at the Lick Observatory as Carnegie research assistant. Her work on the Watson asteroids is being continued by Mr. A. J. CHAMPREUX, Assistant in the Department of Mathematics.

The regular staff of the observatory consists of the Director, one instructor, Dr. RUSSELL TRACY CRAWFORD, and Mr. EINARSON, the assistant. The observatory is very fortunate in receiving a large amount of voluntary service from Dr. GILLIHAN, Dr. BURT L. NEWKIRK, Instructor of Mathematics and Watson Assistant in Astronomy, and Mr .A. J. CHAMPREUX.

The principal function of the observatory being that of instruction, the members of the department are able to devote themselves to astronomical investigations only under great pressure of time. Nevertheless, we have cause to be greatly gratified with the research work that has been accomplished.

The total number of enrollments in the department was two hundred and eighteen, and the number of different courses offered was fifteen. That the members of the department are pressed for time in their own investigations is apparent from the fact that practically all of the instruction is given by the Director and one instructor, the time of the only assistant being absorbed by observatory duties.

The only important additions to the equipment of the observatory are the camera-boxes for the five- and six-inch photographic lenses which have been completed. A few details affecting the convenience of manipulation of the instrument remain to be provided for. A preliminary measurement and reduction, by Dr. NEWKIRK, of a plate made with the six-inch lens (equivalent focal length 32″) indicates that a position of a well-defined object can be obtained from the measurement of a plate made with this instrument with an accuracy of about a second of arc.

Instruction is given chiefly to three classes of students,—viz., to those who elect the study of astronomy for culture purposes, to those who take up practical astronomy as a part of the engineering curriculum, and to a select few who desire a thorough training for the profession, either as practical or theoretical astronomers, astrophysicists, or geodesists.

There are now not less than five graduate students in the University who are preparing for the degree of Doctor of

Philosophy in Astronomy. Three of these hold fellowships in the Lick Observatory, and spend one semester each year in graduate work at Berkeley. One holds a position as Carnegie Research Assistant in the Lick Observatory. Two of the five are specializing in astrophysics, the other three in celestial mechanics. A thorough training in practical astronomy is offered both at the Lick and the Students' observatories.

The principal work of research of the Director has been on the improvement of the methods for computing orbits of comets, asteroids, and satellites. The theoretical results of these investigations are as yet unpublished, but frequent practical applications have been printed during the year in the *Lick Observatory Bulletin* by Dr. CRAWFORD and graduate students who take an active part in these investigations. The new results include an adaptation of the short method to the direct computation of a parabola for comets and of a circular orbit for asteroids, and other modifications to meet special conditions. The new parabolic method has been applied to each of the three new comets of the year. For Comet *a* 1905 two orbits were computed from a short and a long arc by Dr. CRAWFORD and Mr. MADDRILL. They announced the ellipticity of the orbit soon after discovery. For Comets *b* and *c*, two orbits each from a short and long arc were derived by Dr. CRAWFORD and Mr. CHAMPREUX. Comet *b* also appears to be periodic. An extension of the short method was derived from the solution of an osculating orbit of a comet, asteroid, or satellite in cases where these bodies are subjected to large perturbations during the period over which the observations extend. The new method permits of the determination of an osculating orbit from geocentric observations of a material point moving under the attraction of three or more bodies. An application of this method has been made to the seventh satellite of *Jupiter* by Dr. CRAWFORD and Mr. CHAMPREUX. The results are published on another page.

Considerable progress has been made on the perturbations and tables of the Watson asteroids. The chief assistants during the year in this work were Dr. NEWKIRK and Miss HOBE. In addition some fifteen students were engaged at various times as piece-workers. The condition of the work of the twenty-two asteroids is as follows:—

For twelve planets the computations are practically completed, and the results will be published by the National Academy of Sciences as soon as the manuscript is finished. These results include the perturbations of the first order by *Jupiter*, tables from the year of discovery to 1930, a comparison of theory with observation for all available oppositions, and a final correction of the preliminary mean elements. It is proposed to publish the tables in advance of the details of the investigations. These twelve planets are (93) *Minerva,* (101) *Helena,* (103) *Hera,* (105) *Artemis,* (115) *Thyra,* (119) *Althaea,* (128) *Nemesis,* (133) *Cyrene,* (139) *Juewa,* (161) *Athor,* (174) *Phaedra, and* (179) *Klytaemnestra.* In the cases of (93), (101), (103), and (119) our work is based in part on previous investigations by EICHELBERGER and RITTER.

For three asteroids the perturbations have been developed and a preliminary correction of the elements made. These are (104) *Klymene,* (121) *Hermoine,* and (150) *Nuwa.*

Three other asteroids, (106) *Dione,* (168) *Sibylla,* and (175) *Andromache,* belong to the group ½, and special tables have been computed for this group after BOHLIN. Similar tables have been published by v. ZEIPEL. Certain discrepancies between our tables and those of v. ZEIPEL require further investigation. Two asteroids, (94) *Aurora* and (100) *Hekate,* were not originally included in our list, it being supposed that they had been taken up elsewhere. The development of their perturbations is under way. The computations were commenced last year by Dr. NEWKIRK and Miss HOBE, and are being concluded by Dr. CRAWFORD and Mr. CHAMPREUX.

For one asteroid, (79) *Eurynome,* perturbations have been computed by BECKER and tables by EICHELBERGER. A comparison between theory and observations and the correction of the elements remains to be made.

The last of the twenty-two, (132) *Aethra,* is lost. It was strongly disturbed during the discovery opposition. Miss HOBE has undertaken to trace it by applying the new method referred to above for determining osculating elements for an asteroid, by taking immediate account of other attracting bodies besides the Sun. Hitherto not even special perturbations of this planet have been taken account of.

Dr. CRAWFORD has continued in his investigation of the constant of refraction. His first investigation was made in the year 1899, and resulted in the discovery that this so-called constant is a function of the zenith-distance. It was based on a series of observations made with the Repsold meridian-circle of the Lick Observatory during the summer months. The result of this investigation was

$$\triangle \log \mu = + 0.000101 \ (56^\circ.6 - z)$$

An independent investigation of a series of observations made during the winter months gives

$$\triangle \log \mu = +0.000117 \ (59^\circ.3 - z)$$

The two results are entirely independent of each other, and are based on different star-lists. The most probable average result is $\triangle \log \mu = + 0.000108 \ (58^\circ - z)$ by which amount the Pulkova tables should be corrected.

Dr. NEWKIRK has made a thorough examination of the Repsold measuring apparatus after the method employed by GILL. The investigation includes an examination of the scales, of the micrometers, of the straightness of the cylinder which determines the Y axis and of the bar which determines the X axis, of the perpendicularity of these two, and tables of corrections.

Dr. NEWKIRK has also constructed extensive tables for the reduction of photographic measures on the basis of TURNER's formulæ. The tables are to facilitate the transformation from standard rectangular co-ordinates to differences of right ascension and declination, with the converse transformation, and the computation of corrections for refraction, including terms higher than the first order in the measured co-ordinates. They are applicable in the reduction of measures of objects whose right ascension differs from that of the center of the plate by ten degrees or less, and whose declination differs from that of the center of the plate by five degrees or less, no matter what the declination of the center of the plate may be.

As in the past, the students of the University have enjoyed occasional lectures by members of the Lick Ovservatory and others. The department has participated in the regular summer school of the University, a general and a practical course being offered by Dr. CRAWFORD.

The observatory has continued its meteorological and seismographic observations, the former being published monthly.

A. O. LEUSCHNER.

BERKELEY ASTRONOMICAL DEPARTMENT, March 24, 1906.